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Issued March 27, 1913.

U. S. DEPARTMENT OF AGRICULTURE,

OFFICE OF PUBLIC ROADS—BULLETIN NO. 47.

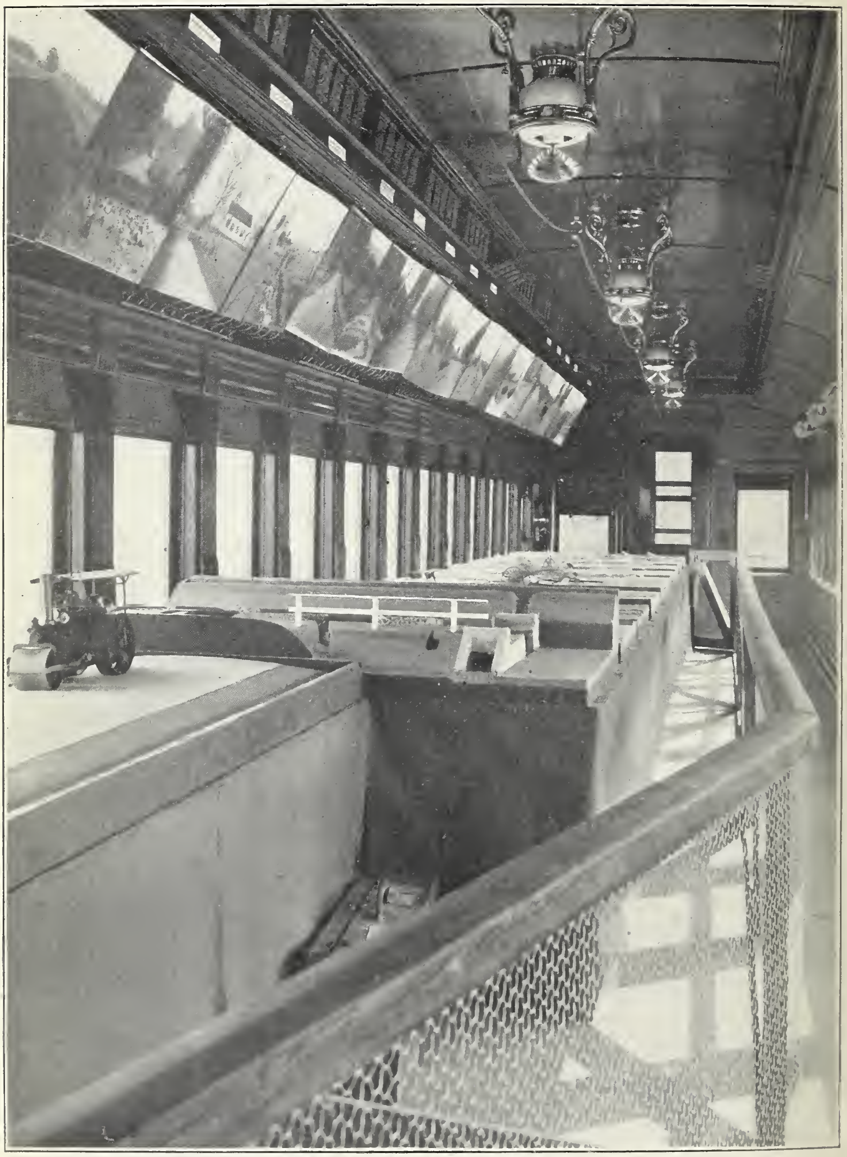
LOGAN WALLER PAGE, Director.

DESCRIPTIVE CATALOGUE
OF
THE ROAD MODELS OF THE OFFICE OF PUBLIC ROADS.

PREPARED BY THE OFFICE OF
PUBLIC ROADS.

(Revision of Office of Public Roads Bulletin No. 36.)

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1913.



VIEW OF A TRAIN EXHIBIT FROM THE OFFICE OF PUBLIC ROADS.

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OFFICE OF PUBLIC ROADS.

LOGAN WALLER PAGE, *Director.*
PAUL D. SARGENT, *Assistant Director.*
VERNON M. PEIRCE, *Chief Engineer.*
L. I. HEWES, *Chief of Economics and Maintenance.*
ALBERT T. GOLDBECK, *Testing Engineer.*
CHARLES S. REEVE, *Assistant Chemist.*
E. W. JAMES, *Chief Inspector.*
M. O. ELDRIDGE, *Assistant Chief of Economics and Maintenance.*
EDWIN C. E. LORD, *Petrographer.*
WILLIAM W. SNIFFIN, *Editorial Clerk and Librarian.*
W. CARL WYATT, *Chief Clerk.*

LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Office of Public Roads,
Washington, D. C., December 3, 1912.

Sir: I have the honor to transmit herewith a manuscript entitled "Descriptive Catalogue of the Road Models of the Office of Public Roads," which is a revision and enlargement of Bulletin No. 36 of this office. Since its publication several new models have been built and the construction of others has been improved. In all sections of the United States the demand for the exhibition of road models is increasing, with a corresponding demand for this illustrated descriptive bulletin, which was first published as an unnumbered document at the time of the Alaska-Yukon-Pacific Exposition. I therefore request that it be printed as Bulletin No. 47 of this office.

Respectfully,

Logan Waller Page,
Director.

Hon. James Wilson,
Secretary of Agriculture.

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DESCRIPTIVE CATALOGUE OF ROAD MODELS OF THE OFFICE OF PUBLIC ROADS.

INTRODUCTION.

The Office of Public Roads of the United States Department of Agriculture made an exhibit of road models for the first time at the Alaska-Yukon-Pacific Exposition. The aim was to put on view such striking examples in miniature of model roads that visitors would not only appreciate the beneficent effects of improved highways, but would, at the same time, be able to understand the methods of their construction.

Since the Alaska-Yukon-Pacific Exposition closed the exhibit of the Office of Public Roads has been displayed at Omaha, Nebr., during the National Corn Exposition; at Knoxville, Tenn., during the Southern Appalachian Exposition; at Chicago, Ill., during the National Land and Irrigation Exposition; at New York City during the Travel and Vacation Exposition and the Domestic Science Exposition; at Atlantic City, N. J., during the American Road Congress; at Lethbridge, Alberta, during the International Dry-Land Congress; at Buenos Aires, Argentina, during the International Agricultural Exposition; at Turin, Italy, during the International Exposition; and at various other expositions and fairs. The models have also been displayed on road trains at all important places along the route of the Pennsylvania Railroad in the State of Pennsylvania and along the entire system of the Southern Railroad, the St. Louis & San Francisco Railroad, the Atlantic Coast Line, and the Nashville, Chattanooga & St. Louis Railroad.

The models illustrate standard types of road construction and represent the modern ideas of highway engineers. All of them are built on the scale of 1 inch to the foot, or one-twelfth of the full size. With the exception of the brick model, they represent roads with a hardened surface 16 feet wide and with earth shoulders on each side about 6 feet wide. Owing to climatic conditions and the varying character of local materials, modifications in construction will be found necessary, and if application for expert advice concerning any special road problem is made, the Office of Public Roads is prepared to furnish it free of charge.

The descriptions of the models are so arranged in this bulletin as to present the historic development of road building. The Roman road is described first, and then descriptions are given successively of the French roads, after the ideas of the Romans and of Trésaguet, the roads of MacAdam and Telford, and finally the various types of modern construction. Among the latter are models showing brick, concrete, asphalt block, macadam, sand-clay, gravel, and earth roads. There are other models showing the process of maintenance, resurfacing, and bituminous macadam construction by the mixing, penetration, and prepared-filler methods. One model shows the various methods of draining and strengthening unsuitable bases for road foundations, while another shows a typical method of treating gravel or macadam roads to make them dustless and to prevent their disintegration under automobile traffic.

ROMAN ROADS.

The Romans began building roads on a large scale more than 300 years before the Christian era. The Appian Way, one of the most celebrated of their roads, was begun in 312 B. C., by Appius Claudius Cæcus. This road led from Rome to Capua, a distance of 142 Italian miles. It was later continued to Brindisi, making the total distance 360 miles. Rome continued as a great road-building nation for about 600 years, and some of its roads remain in part to the present time. The Appian Way is said to have been in perfect condition more than 800 years after its construction.

The Roman construction was often varied, though always extremely massive. The general form of construction employed during the reign of Cæsar Augustus, when Roman road building seems to have reached its height, was a massive road from 16 to 30 feet wide, from 3 to 4 feet thick, and laid in 3 or 4 courses. The first course was almost invariably of large, flat, field or quarry stones laid on earth, except in swamps, where poles, logs, brush, or even boards were used beneath the stone course. The other courses varied extremely with the available material and the period and importance of the road. Small stone with and without mortar, gravel mixed with clay, broken brick, tiles, etc., and even earth was used for the second and third courses. The surface or wearing course consisted of well-cut, irregular, close-fitting polygonal blocks on a few of the more important roads, but more often it consisted of uncut stones, not unlike our cobblestone pavements, or of gravel, and in some cases of a mixture of sand and clay or clay and gravel.

Some of the more important roads near Rome were practically lined with temples, porticoes, and statues. On all roads inscribed milestones were placed at regular intervals.

Plate II, figure 1, shows a model of the Appian Way. This is the highest developed type of road constructed by the Romans.

Section A shows the contignatum pavimentum, composed of lime and sand, straw, rushes, or reeds, and sometimes laid on sills or boards.

Section B shows the statumen, or foundation, composed of two courses of flat stones laid dry or in lime mortar. The depth of this course was from 16 to 18 inches.

Section C shows the rudus, or rubble, composed of broken stone mixed with lime in the proportion of 1 part of lime to 3 parts of stone. Sometimes the material was taken from old buildings. This course was laid from 6 to 9 inches deep.

Section D represents the nucleus, composed of coarse gravel and lime used hot, or bricks, potsherds, or broken tile mixed with lime and covered with a thin layer of lime mortar.

Section E shows the summa crusta or pavimentum, consisting of polygonal blocks joined with the greatest nicety. This course was about 6 inches deep and about 16 feet wide.

Section F indicates the curbs, which were 2 feet wide and 18 inches high, with upping blocks as shown in the illustration. These blocks served as seats for travelers and as mounting blocks for riders.

Section G shows a side road, the surface of which was composed of gravel flushed with mortar. The width was from 6 to 8 feet.

FRENCH ROADS.

From the viewpoint of construction, road building in France may be divided into three periods—the period of Roman influence, the period of Trésaguet, and the modern period.

By the time that road building was revived in France in the seventeenth century the Roman methods of road building had been greatly modified, though the Roman form, especially in the foundation, was still retained. Under the ministry of Colbert (1660–1669) as controller general of finances, about 15,000 miles of stone roads were built, practically all with an undrained foundation consisting of one or more layers of large flat stones placed in the bottom of a trench-like excavation. These stones were then covered with a thick layer of more or less finely broken stone. As no systematic maintenance was attempted, the roads rutted badly, and it was only rarely that the broken stone consolidated properly. The total thickness of the roads was from 1½ to 2½ feet.

About 1775 a form of construction, supplemented by continual maintenance, came into prominence in France. It had long been advocated by Pierre-Marie-Jérôme Trésaguet, a noted French engineer. He held that good drainage and systematic maintenance were absolutely necessary to have good roads. By providing a properly crowned and drained foundation, he reduced the required thickness more than one-half and provided a better and more serviceable road. The small stones were broken more uniformly and, by a little attention after placing, soon bonded under the traffic. The roads became smooth and afforded comfortable traveling.

By 1830 most of the great highways of France had been completed. The roads remaining to be improved were largely of the secondary class. For such roads the macadam method was adopted almost exclusively. At the present time road building in France is confined largely to the "vicinal" and rural roads and to the necessary reconstruction and maintenance of the roads already built.

FRENCH CONSTRUCTION PREVIOUS TO 1775 (ROMAN METHOD).

Plate II, figure 2, illustrates the type of road constructed in France previous to 1775. This type was modeled on the Roman system.

Section A shows the earth foundation, which was flat.

Section B represents the stone foundation. This course was composed of flat stones laid by hand in two or more layers. The total width of this foundation was 18 feet, and the depth was from 9 to 10 inches.

Section C shows the layer of small stones, which were broken in place with hand hammers.

Section D shows the finished surface. This course was composed of stones broken by hand into sizes smaller than the underlying material. It was left to be consolidated by traffic. The total thickness of the road in the center was from 18 to 20 inches and at the sides from 12 to 14 inches.

TRÉSAGUET METHOD.

Plate III, figure 1, illustrates the type of road constructed in France by Trésaguet from 1775 to 1830. After this period the macAdam method was used almost exclusively.

Section A shows the earth foundation parallel to the finished surface.

Section B represents the stone foundation, which was composed of flat stones laid on edge, lengthwise across the road, and beaten to an even surface. The depth of this foundation was about 5 inches.

Section C shows the small stones laid and beaten by hand hammers. The finished layer was composed of broken stones about the size of walnuts and was spread with a shovel.

Section D represents the finished road as consolidated by travel. The crown was made 6 inches, the width 18 feet, and the total thickness about 10 inches.

E shows the curbs, which were composed of rough, flat stones, set on edge. The upper edge was made flush with the surface.

MACADAM METHOD.

The macadam method of construction was introduced in England and Scotland by a Scotchman, John Loudon MacAdam (1756–1836). The chief features of MacAdam's construction were a raised, thoroughly drained, and crowned earth foundation, stone broken to uniform size not to exceed 1½ inches, and the addition of no binding material to the broken stone. MacAdam also insisted that the road should have a slight crown and that broken stone, when spread on the road, should be kept raked smooth until thoroughly consolidated by the traffic. This form of construction continued practically unchanged until the introduction of the road roller in about 1870.

During the past 40 years the methods of construction and maintenance have been greatly modified, though the same name is still given to roads of this class.

At the present time, the macadam road is built in courses, with the coarser stones at the bottom and the finer on top. Stone screenings or sand are used for binding, while practically in every case the stone is broken by machinery.

Plate III, figure 2, illustrates a macadam road of the type constructed during the first period of macadam construction, which began about 1816.

Section A shows the earth foundation, which was always made higher than the surface of the adjacent ground so as to facilitate the escape of water from the foundation and the surface. MacAdam did not believe that an excavated foundation was necessary.

Section B shows the layer of hand-broken stone, with a depth of 10 inches. This stone was broken to sizes weighing 6 ounces, and no stone was permitted to exceed 1½ inches in its greatest diameter. The surface of the road was raked regularly during the process of consolidation. No rollers were used, and the stone was compacted by traffic.

Section C shows the finished road, from 16 to 18 feet wide. The crown was just enough to shed water—that is, from 4 to 6 inches. MacAdam contended that the stones would lock or bond by virtue of their angularity and so make a water-tight crust, and that it was neither necessary nor desirable "to bond a road with earth, clay, chalk, or other material that would imbibe water or be affected by frost." The surface of the road was kept even and smooth by the addition of fresh material where necessary. This material was placed on the road in thin layers in damp weather in order that the new material might more readily bond and incorporate with the old.

TELFORD METHOD.

This form of construction takes its name from the celebrated engineer Thomas Telford (1757–1834), who, among many other notable things, constructed 920 miles of roads in the Highlands of Scotland and also a large mileage in the mountainous sections of Wales, as well as in the north of England. To-day the chief characteristic of the Telford road is a foundation of fairly regular stones, about 3 by 5 by 7 inches in their smallest dimensions, placed by hand on the wider of the long narrow faces and with the greatest dimension perpendicular to the axis of the road. The blocks are then "keyed in" by filling the interstices with stone spalls, chips, or small gravel. Any projecting points are broken off. On this foundation is placed a wearing surface of broken stone from 4 to 7 inches deep. Originally the telford road was constructed with a flat subgrade, and a slight crown was obtained by using larger stones in the center. In present construction, however, the subgrade is given the same crown as the finished road, and stones of uniform size are used throughout. Formerly, too, the wearing surface was placed and consolidated in the same manner as the wearing surface of the old macadam road.

The telford foundation is used very generally in the construction of important roads in Austria-Hungary, Germany, Russia, Switzerland, and the Scandinavian countries. Some of the roads of England and Scotland which were formerly macadam are proving too weak for the present heavy traffic and are being relaid with telford foundations.

Plate IV illustrates a telford road as constructed during the first period, which began about 1820.

Section A shows the earth foundation, from 16 to 20 feet wide, and flat.

Section B represents the telford base, composed of stones about 7 inches in depth. No stone more than 3 inches wide was placed at the top.

Section C shows the top course, about 7 inches thick at the crown. It was composed of hand-broken stone, not heavier than 6 ounces, and passing through a circular ring not larger than 1½ inches in diameter.

Section D shows the finished road, bonded with 1 inch of gravel. The crown was made 6 inches for the road, which was surfaced to a width of 18 feet.

FOUNDATIONS OR SUBGRADES AND SHOULDERS.

In the construction of all types of gravel or macadam roads it is necessary, in order to obtain the best results and to use surfacing material economically, to prepare the foundation or subgrade and shoulders of the road carefully. The subgrade should be brought approximately to the grade established for the road, and as much lower as the depth of the surfacing material to be used. It should then be compacted with a roller until it is hard and firm. If soft places develop during the rolling, they should be filled with good material and rolled again. This prevents the surfacing material from being pressed into the foundation, and consequently less material is required. The subgrade should also be finished with a crown for the reason just stated. If the surface is to be of uniform thickness, the crown of the subgrade is the same as for the finished road. If the surfacing material is to be thicker at the center than at the sides, the subgrade must be made to correspond. The shoulders are built up before the surfacing material is placed in position and serve not only to increase the width of the road but as a side support to hold the surfacing material while it is being rolled. They also keep it from wasting away into the side ditches. After the hardened surface is completed, the shoulders should be finished to correspond; shoulders are usually finished with a sharper crown than is given the hardened surface.

Plate V shows several methods of improving and strengthening poor natural foundations. This is accomplished principally by drainage, and as the need for some such treatment occurs more generally in hilly or rolling country than elsewhere, this model represents a roadbed located partly in a cut and partly on a sidehill.

Section A represents a sidehill location, and shows a surface ditch at the top of the slope, a side drain opening into a culvert with a drop inlet, a telford base, and a section of guard rail.

Section B shows a V stone drain foundation with a side outlet.

Section C shows a center drain with laterals and cobble gutters.

SECTION A—SURFACE DITCH, SIDE DRAIN, AND TELFORD FOUNDATION.

The surface water falling on a large area sloping toward the road is often kept from the road and out of the road gutters, where it usually does considerable damage, by a surface ditch such as the one represented in Plate V. The side drain is constructed to carry off the ground water which is often found in hilly sections. In the model the trench is represented to be 2½ feet deep, 12 inches wide at the bottom, and 18 inches wide at the top. On the bottom of the trench is placed about 2 inches of clean stone, and on this stone a tile pipe, usually about 5 inches in diameter, is laid. The pipe is laid without cement, and the loose stone is carefully filled around the sides and top of the pipe to the top of the trench. The side drain empties in some suitable outlet. For example, the one in this model empties in a drop inlet, which also serves as an outlet to the surface ditch. The drop inlet empties into a culvert, and the water is carried under the road. This type of inlet furnishes an easy means for inspecting and cleaning the culvert. It also prevents the bank from sliding and closing up the inlet of the culvert, which sometimes happens in hilly sections.

The telford base is an old form of construction used largely in wet sections. This construction has been described under the heading "Telford method" (p. 12).

The guard rail shown in the model is to protect travelers along the steep slopes. The fence is usually painted to prolong its life and colored white to enable the public to discern the embankment at night. The posts are about 6 inches in diameter and about 7 feet long, and are set in the ground to a depth of 3½ feet. About 18 inches from the ground a plank, 2 by 6 inches, is notched into the posts. The top rail is then placed about 18 inches above the top edge of this plank. It may be either a plank, 4 by 4 inches, notched into the top of the post or a plank, 2 by 6 inches, spiked to the top of the post, which has been sawed off with a slope of 3 inches.

SECTION B—V STONE DRAIN FOUNDATION.

The V stone drain foundation is shown in section B of Plate V. This form of drainage is cheaper than the telford method and, in a section of country where rock abounds in ledges, it is also cheaper than the side drain construction. It is used entirely in wet and spongy sections. The water is held at the point of the V until a suitable outlet can be secured. The center is usually excavated 2 feet and the sides about 16 inches below the finished grade. The material excavated is thrown to the sides, forming the shoulders. In swamp sections it is sometimes necessary to haul material for the shoulders. The V drain is then filled with stone to a depth of 18 inches at the center and 10 inches at the sides. These stones grade from 8 inches in thickness down to a few inches. The large-sized stones are placed at the bottom, while the small stones are used at the top. The surface should then be rolled and the surfacing material spread and rolled. V drains are sometimes built of brickbats, slag, or even sand, or any material that will permit the water to seep rapidly to the point of the V. This type of construction permits the use of field stone of an inferior type and assists in clearing many farm lands of an otherwise waste product.

SECTION C—CENTER DRAIN WITH LATERALS AND COBBLE-PAVED GUTTERS.

The center drain with laterals, sometimes called a blind or French drain. furnishes another mode of draining the foundation of a road. As with the V drain, the water is brought to the center of the road and conducted to some suitable outlet. The model (Pl. V) shows these drains about 2 feet deep, about 12 inches wide at the bottom, and about 18 inches wide at the top. The trench is filled with stones from a few inches in thickness up to 8 inches.

The cobble gutters show an effective way of carrying away surface water on steep grades. The stones vary in thickness from 8 to 12 inches and are laid on a sand or gravel base. They are well rammed and given a coat of sand, which is carefully swept in, and then the stones are rammed again. These gutters are easily cleaned and protect the banks from being undermined, while at the same time carrying the water along rapidly without damage to the road.

EARTH AND SAND-CLAY ROADS.

The mileage of roads in the United States is so vast and the traffic on many of the country roads is so light that it is out of the question to improve more than a small percentage of these roads with a hard surface. This does not mean, however, that all other roads must be neglected. They should be improved just as far as their importance and the traffic will warrant. The common clay roads may be vastly improved by a little judicious grading and systematic maintenance.

In many cases, especially in the vast regions of the South, most of the common roads may be improved, for all practical purposes, merely by the addition of sand or clay, as the case may require, and incorporating this with the surface soil of the road. Thousands of miles of sand-clay roads have already been built in the Southern States at an average cost of about $750 per mile. These roads are almost without exception answering the purposes as well as a far more expensive form of construction would do.

EARTH ROADS.

Plate VI, figure 1, illustrates the construction and maintenance of an earth road. Such roads should be worked when they are damp and soft. The material can then be handled more economically and the resulting road surface will be more satisfactory. After earth roads have once settled down in the spring or summer, they should not be disturbed. If work is then attempted, the material will be brought upon the road in clods, which make only a rough surface when dry and an excess of mud when wet.

Section A shows the old and unimproved roadbed.

Section B illustrates a section of earth road under improvement, together with a road machine or grader. The width of the section shown is equivalent to about 33 feet of finished surface from ditch to ditch.

Section C illustrates an earth road which, though surfaced by a road machine, has rutted under heavy traffic and is being maintained by the split-log drag. In the road illustrated by sections B and C, the crown or slope from the center to the sides is equivalent to 1 inch to the foot.

The surface of section A is characteristic of altogether too many earth roads, in that the center is several inches lower than the sides. This faulty condition makes it impossible for the water to run from the surface; and, even if this were possible, there are no roadside ditches to carry it away. In consequence, the road is usually full of puddles, and cut up with ruts and mudholes.

Section B illustrates the use of a reversible road machine in opening roadside ditches and in shaping the road surface so that it will shed water. The work of this machine is equivalent to the labor of many men, and it is done far better than can be done with shovels and picks. An earth road should have a width of at least 20 feet, or, better still, 24 or 30 feet. If the road is narrow, there is a tendency to use only the narrow central portion, and wagons running in the same rut soon create a water-holding depression. The surface drainage can be provided for by giving the road an average crown or slope from center to sides of 1 inch to the foot. On some soils the crown could be even less than that, but seldom greater. On all earth roads, except sandy sections, side ditches should be built as shown in section B. They can be made and maintained with a road machine, but care should be taken that they have a fall sufficient to carry the water along the side of the road. Through wet and swampy land it is often necessary to raise the roadbed above the general level of the country in order to secure drainage.

For continuous maintenance the split-log drag shown in section C has been devised. This little model has been built to the same scale as the road model—1 inch to the foot. It can be made best from a log 7 or 8 inches in diameter and from 6 to 8 feet long. The log should be carefully split and the halves fastened together with stakes, with the flat sides vertical and facing to the front. The logs, though of the same length, are attached so that the end of the rear log is from 16 to 20 inches nearer the center of the road than the end of the front one. An ordinary trace chain and a set of doubletrees are then attached. When the horses move forward, the drag should slide along the road at an angle of about 45 degrees, with the forward end nearest the ditch, so that it moves the earth toward the road center.

In the construction of this implement care should be taken to make it light enough for one man to be able to lift it. The best material is a dry red-cedar log, though red elm and walnut are excellent, while box elder, soft maple, elm, or willow are superior to oak, hickory, or ash. A broad platform is usually placed on the cross stakes, helping to strengthen the implement and giving a place for the driver to stand. After a little practice a man can learn how best to distribute his weight so as to make the drag cut, spread, and pack the earth properly.

Dragging across the ruts, up one side of the road and down the other, is all that should be undertaken the first time, but this should be repeated after each heavy rain. As a mile of road can be dragged in a few hours, the split-log drag provides a simple and inexpensive method of road maintenance. If it is used in conjunction with the road machine, fairly good earth roads can be secured at a nominal expense. Dragging is done for 50 cents per mile in some parts of the country. At this rate, a mile of earth road can be dragged once a month for a year for $6. Some remarkable results have been accomplished with the drag without the aid of the road machine. Farmers' Bulletin 321,[1] "The Use of the Split-log Drag on Earth Roads," deals fully with this subject.

SAND-CLAY ROADS.

Plate VII illustrates the construction of a sand-clay road 16 feet wide and 8 inches thick when compacted. The crown as shown is 1 inch to the foot.

Section A represents an unimproved sand road about 33 feet wide; section B, an old sand road slightly rounded to receive the clay, and with the center about 4 inches higher than the sides; section C, a portion of road covered with clay to a depth of 6 inches; section D, the harrowing or mixing process; and section E shows the completed road.

The bottom of the ditch of a completed road of this type should be about 16 inches lower than the road at the center, so as to give an average slope of 1 inch to the foot.

As a general rule, sand-clay roads are built on sandy foundations, and it is the usual practice to put the clay on the unimproved foundation, but better results will be obtained if the sandy foundation is given a slight crown. This makes the center from 4 to 6 inches higher than the side ditches. If this is not done, more clay will be necessary to give the road the needed crown, and that is expensive, especially if the material has to be hauled a considerable distance. The process is as follows:

The road is covered with from 4 to 6 inches of clay and worked with a disk or tooth harrow until thoroughly mixed, first dry and finally wet. The final mixing should be done, if possible, during rainy weather. When the mixing has been done, the surface is brought to a crown with the road machine or split-log drag and covered with a thin layer of sand. After two or three rains it may be found necessary to apply another sand coat. This method produces a smooth, cheap, and satisfactory road suitable for light traffic.

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[1] Copies of this publication will be sent free to persons applying to the Secretary of Agriculture, Washington, D. C.

Similar results can be secured by adding sand to a clay road and providing good surface drainage. When building on a clay foundation, it is advisable to plow the clay before adding the sand in order to insure a thorough mixing. Farmers' Bulletin 311,[1] "Sand-clay and Burnt-clay Roads," and Circular 91[1] of this office, "Sand-clay and Earth Roads in the Middle West," give full information on this subject.

GRAVEL ROADS.

Plate VIII illustrates a properly constructed gravel road 16 feet wide, 6 inches thick at the center and 4 inches thick at the sides when rolled. The crown as shown is three-fourths inch to the foot. The road is graded for a width of 33 feet.

Section A represents a subgrade or foundation prepared as previously described, with the center about 10 inches higher than the bottom of the side ditches.

Section B shows the first course of gravel, which, after rolling, has a depth of about 4 inches at the center and about 3 inches at the sides.

Section C represents a second course after rolling. There the material is about 2 inches in depth at the center and 1½ inches at the sides. The crown or side slope of this road from center to sides is at the rate of three-fourths inch to the foot. In constructing a gravel road the best results will usually be obtained by separating or screening the materials into sizes. For the bottom course material ranging from 1¼ inches to 2½ inches should be used, while for the top course material ranging from 1¼ inches to one-fourth inch should be used. The best and cheapest method of screening gravel is by using the rotary screen, with holes 2½, 1¼, and three-fourths inch wide. Gravel should contain from 16 to 20 per cent of clay or other binding materials to bond it properly. Roads of this type should be constructed as early in the spring as possible in order to give them time to consolidate thoroughly before the fall and winter rains.

Section C also illustrates how the shoulders shown in the other two sections are finished to correspond with the gravel surface. When plenty of gravel can be obtained cheaply, it will be found more satisfactory to use it for surfacing the whole width of the road than to use it, as above described, with earth shoulders. When it is used in this way, the gravel surface may taper from 6 inches in thickness at the center to 2½ or 3 inches at the edge of the road.

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[1] Copies of this publication will be sent free to persons applying to the Secretary of Agriculture, Washington, D. C.

MACADAM ROADS.

WATER-BOUND MACADAM ROADS.

Plate IX illustrates the construction of a macadam road 16 feet wide, 6 inches thick at the center and 4 inches thick at the sides when rolled. The crown as shown is five-eighths inch to the foot. The road is graded for a width of 33 feet.

Section A represents the prepared subgrade properly crowned and rolled; section B, the first course of broken stone, 4 inches thick compacted; section C, the second course, 2 inches thick compacted; and section D shows the finished road, an example of which is shown in Plate X.

In the model the crown or slope of the foundation is about the same as in the finished road, giving an average fall of about three-fourths inch to the foot from center to sides. In preparing for the construction of a road of this type it is advisable to roll the foundation thoroughly when the soil is damp, so that all soft spots may be found and filled and that the ground may be prepared firmly and smoothly for the first layer of stone. Shoulders are built on both sides to hold the macadam in place, either by excavation or by piling up the earth shoulders as the work progresses. The shoulders should never be less than 3 or 4 feet wide, and, if possible, they should be 6 or 8. If they are sufficiently wide and have a slope of not more than 1 inch to the foot, they can be used in dry weather for light traffic and thus relieve the macadam of fast travel, which causes it to ravel.

In every case the bottoms of the side ditches should be lower than the road foundation to insure proper drainage. If the road is built of clay or heavy soil, shoulder drains should be built at low places to lead the water from the foundation to the side ditches. These drains are filled with crushed rock or gravel and are covered with soil. The side ditches should be shallow, but wide; their construction is based on the volume of water they may be expected to carry.

The No. 1 crushed rock for the foundation may vary in size from 1½ to 2½ inches in diameter. The depth of this course must depend upon the conditions. If built on light gravelly soil, where little traffic may be looked for, a depth of 3 or 4 inches is sufficient, but for heavy soils and constant traffic the course should be from 4 to 6 inches deep after rolling. For roads 12 feet wide or less the depth of material should be uniform throughout, but if the road is from 14 to 16 feet wide the total depth of both courses may be reduced to 6 inches at the center and 4 inches at the sides.

After the foundation course has been thoroughly rolled the second course, varying in size from three-fourths to 1½ inches, is applied. While rock of inferior quality may be used for the foundation course, nothing but the best hard and tough rock should be used for the surface. It should not only be able to resist the pounding and grinding of traffic, but should have a high cementing value, so that the fine particles will bind the surface into a water-shedding crust. All rolling should start at the side and continue toward the center.

The final course of screenings does not add to the depth of the road, which when completed should be flush with the earth shoulders. The total depth of roads of this type varies from 4 to 12 inches, according to local conditions, but the average depth of such roads in the United States is not more than 6 or 7 inches.

In spreading the surface-bonding course of screenings, the stone may vary from three-fourths inch to dust. It is not necessary to separate the dust from the screenings unless the amount of dust is excessive. If too much dust is used the road will be sloppy in wet weather and dusty in dry, while if there is not a sufficient quantity of screenings the road will quickly ravel, especially under fast automobile traffic.

Care and judgment must be exercised in determining the proper amount of screenings and also in spreading them. One thin layer should be spread and rolled and then sprinkled and thoroughly rolled, after which another layer should be spread. By continuing this process until all voids are filled and the surface has been thoroughly consolidated a waterproof surface will be secured.

In the foreground of the frontispiece (Pl. I) is shown a miniature steam roller, which is intended to emphasize the importance of road rolling. In the long run better and cheaper work can be done with a power roller than with a horse roller, and this type may also be used to advantage in road repair work. If the road surface becomes uneven or rutted, it can be spiked up by teeth placed in the wheels of the roller. Then the surface can be leveled off and resurfaced with another course of No. 2 stone, after which it may be rolled and treated again with screenings. Farmers' Bulletin 338,[1] "Macadam Roads," gives additional information on this subject.

BITUMINOUS MACADAM ROADS.

Since the coming of the automobile, with the consequent aggravation of the dust nuisance, numerous methods have been devised to secure a lasting road surface which would at the same time be within the financial means available for main-line country roads and reasonably free from dust. Probably the most important of these is the group of methods generally classed as bituminous construction.

While these several methods differ greatly as to name and the details of carrying out the work, the fundamental aim of each is the same. This is to secure a smooth, waterproof, and durable surface composed of mineral aggregate, usually broken stone, and bonded in part by the mechanical interlocking of the fragments and more firmly by a bituminous material coating the fragments and filling the interstices. Tars, asphaltic oils, liquid asphalts, tar and asphaltic preparations, and asphalt are the binders more commonly employed.

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The usual methods of construction are known as the mixing method, the penetration method, and the filler method. In the mixing method a more or less closely graded aggregate is mixed either by hand or machinery with the proper amount of bituminous binder before placing it on the road. In the penetration method the wearing or second course of stone is laid and rolled as in ordinary macadam; but instead of applying the screenings, hot bitumen is sprinkled or sprayed over the stone in sufficient quantity to coat the fragments and penetrate to a depth of 2 or 3 inches. In the filler method the surface or second course usually is placed in two layers. The first layer is partly rolled and then pea stone or stone chips which have previously been well coated with bitumen are added and the second layer of stone is placed on top of the chips. The pressure of the roller will force a portion of the chips downward in the interstices of the partly rolled stone, while the remainder will work upward, bonding the entire surface course. In some cases the surface course is raked with a tooth harrow in order to mix the chips better with the second course. In each of these forms of construction it is customary to sprinkle a light application of hot bitumen over the surface in order to fill the voids completely and make the surface waterproof. A sufficient quantity of sand, pea gravel, or stone chips is then added to take up any excess of bitumen, the surface is rolled thoroughly, and the road thrown open to traffic.

PENETRATION METHOD.

Plate X illustrates the construction of a bituminous macadam road built according to the penetration method.

Section A represents the prepared subgrade 16 feet wide, with the crown one-half inch to the foot; section B, the first course of No. 1 stone, 4 inches compacted after rolling; section C, the second course of No. 2 stone, 2 inches compacted after rolling; section D, the application of bitumen at the rate of about 1½ gallons to the square yard; section E, the application of stone chips, after being rolled; section F, a bitumen paint coat applied at the rate of about one-half gallon per square yard; and section G shows the completed surface, with clean stone chips lightly rolled, and the crown of the finished road, representing an average fall of about one-half inch to the foot.

The construction of this road, through the application of the No. 1 and No. 2 courses, is the same as an ordinary macadam road. It varies from the method of construction of a macadam road in that hot tar or asphalt is flushed into the No. 2 course before the screenings are applied.

After the application of hot tar or asphalt a light coat of clean stone chips is spread and rolled lightly into the surface. Following this process a paint coat of hot tar or asphalt is applied and another layer of screenings spread and rolled into the surface.

MIXING METHOD.

Plate XI illustrates the construction of a tar, oil, or asphalt macadam road, built according to the plan ordinarily referred to as the "mixing method."

Section A illustrates the prepared subgrade 16 feet wide, with the crown one-half inch to the foot; section B, the first course of No. 1 stone compacted to a depth of about 4 inches; section C, the second course of bitumen-covered stone spread to a depth of about 2 inches when compacted; section D, the application of a layer, about one-fourth inch thick, of bitumen-covered sand or stone chips, which, after being rolled firmly into the surface voids, should add nothing to the thickness of the road; and section E shows the completed surface and the clean chips or sand lightly rolled, leaving the road with a sloping crown of about one-half inch to the foot. The course of bitumen-covered stone is prepared by applying sufficient hot bitumen to cover a graded mineral aggregate when mixed. This graded aggregate is composed of No. 2 stone and stone ranging in size from three-fourths inch to dust in proportions of 960 pounds to 350 pounds.

Before applying the bitumen-covered sand this course must be thoroughly rolled and the sand then applied in such quantities that it will fill the surface voids and bring the surface to a smooth and even condition. The final coat of stone dust is applied merely for the purpose of taking up any excess of bitumen and of giving the road a pleasing appearance.

PREPARED-FILLER METHOD.

Plate XII shows the construction of a bituminous macadam road built according to the prepared-filler method.

Section A represents the prepared subgrade, which has a crown of three-fourths inch to the foot and is well rolled.

Section B shows the first course of No. 1 broken stone. The stone varies in size from 1¼ to 3 inches and is placed to a depth of about 5½ inches loose or 4 inches rolled.

Section C represents the second layer of broken stone. The size of the stone in this layer varies from three-fourths inch to 1¼ inches.

The stone is spread to a depth of about 3 inches loose or 2½ inches rolled.

Section D illustrates the application of the bituminous prepared filler, spread to a depth of about 1½ inches. The filler is made up as follows: Stone chips from one-eighth to three-fourths inch, sand, and from 7 to 12 per cent bitumen, each heated separately and mixed. The mixture is applied hot.

Section E represents the mixing of the prepared filler with the No. 2 stone, by means of harrowing. The harrowing is continued until the No. 2 stone appears in the surface, after which the filler is thoroughly rolled with a steam roller.

Section F represents the second layer of filler, which is spread to a depth of about one-half inch and thoroughly rolled.

Section G shows the application of a light covering of screenings to take up the surplus bitumen, after which a thorough rolling completes the road.

ROCK-ASPHALT MACADAM ROADS.

Plate XIII represents a rock-asphalt macadam road surfaced to a width of 16 feet. The macadam is compacted to a total depth of 8½ inches and the crown is made one-half inch to the foot. The rock asphalt is spread on the road at the rate of 80 pounds to the square yard.

Section A represents the prepared subgrade; section B, the first course of stone, ranging in size from 2 to 3 inches, with a depth of 3 inches when compacted; section C, the second course of stone, ranging in size from 2 to 3 inches, filled with stone chips or sand and having a depth of 3 inches when compacted; section D, the third course of stone, ranging in size from 1½ to 2½ inches, with a depth of 2½ inches when compacted; section E, the rock asphalt, to the extent of 40 pounds per square yard, or about three-fourths inch loose, rolled in to fill the voids; and section F shows the finished surface, composed of rock asphalt, spread at the rate of 40 pounds per square yard, which is equivalent to a course about three-fourths inch thick before rolling.

MAINTENANCE OF MACADAM ROADS.

SURFACE TREATMENT.

The surface treatment of an old macadam road with tar or oil is shown in Plate XIV.

Section A shows a disintegrated macadam surface; section B, the surface after sweeping; section C, the application of oil or hot tar at the rate of about one-half gallon per square yard; and section D, the application of sand to the oiled surface, completing the treatment.

Before any application of oil or tar is made all loose material should be removed and the road surface should be absolutely dry. In applying tar or oil a number of methods may be adopted. It may be poured by hand, or by means of a sprinkling wagon. The liquid should be thoroughly broomed into the oil surface before the sand is applied, in order to secure perfect cohesion. Enough sand should then be applied to take up any excess of tar or oil that may be left on the surface.

RESURFACING MACADAM ROADS.

Plate XV illustrates the restoration of a macadam road to its original condition after it has become badly worn. The macadam width as shown is 16 feet, and the crown is one-half inch to the foot.

Section A represents the worn macadam surface; section B, the surface after spiking; section C, the road after it has been recrowned; section D, the application of 2 inches of new stone, compacted after rolling; section E, the application of tar or asphalt by the penetration method at the rate of about 1½ gallons per square yard; section F, the application of stone chips after being rolled; section G, a tar paint coat averaging about one-half gallon per square yard; and section H, the finished surface.

This model illustrates the usual custom of restoring a macadam road which has become badly worn and rutted, owing to excessive travel and lack of maintenance. It shows that unless roads are given proper maintenance at the proper time it will become necessary to make extensive repairs at some time in the future.

PAVED ROADS.

Paved roads are sometimes advisable where there is heavy traffic. The materials which have been adapted to country roads during the past years are brick, asphalt block, and a small stone block extensively used in Germany and known as "kleinpflaster."

A good paving brick laid on a sand cushion with a substantial concrete foundation makes a road well adapted to both horse-drawn and motor traffic. The first cost of such a road is generally high, but this is largely offset by its durability and low maintenance cost.

Asphalt blocks are molded under pressure from sand, broken stone, and asphalt into rectangular blocks, which are laid on a concrete foundation somewhat in the same manner as brick. The asphalt blocks are more resilient than the brick and consequently freer from noise. They have as yet not been used to any great extent on the country roads of the United States. The small sett, or "kleinpflaster," pavement of Germany is as yet almost unknown in this country. A hard, tough rock, preferably basalt or diabase, is broken by machinery into cubes 3 to 4 inches in size. These are placed on a light sand cushion with a concrete or old macadam base as foundation. In Germany they are generally laid in an oyster shell or mosaic pattern, while in Hungary and Austria they are laid in rows at 45° to the axis of the road. This pavement may be laid at a fairly low first cost, is not expensive to maintain, is neither noisy nor slippery, and is well adapted to mixed traffic.

CONCRETE ROADS.

Concrete roads are a comparatively new development in the effort to find a material which will successfully withstand both automobile and horse-drawn traffic. Concrete pavements were laid first in 1869 in Grenoble, France, where many streets are still paved with this material. In this country the first use of the concrete pavement was probably in Bellefontaine, Ohio, where several sections were laid in 1893 and 1894.

The largest use of concrete in building improved country roads at present is to be found in Wayne County, Mich. These roads are built of a $1:\frac{1}{2}:3$ mixture throughout, with a minimum thickness of 7 inches. The width of the surfaced roadway varies from 9 to 24 feet. The county road officials are very well pleased with this form of construction, and many miles of new concrete roads are being built.

In other cases a leaner concrete is used, and the surface is protected from the immediate impact of traffic by a cushion coat formed of some bituminous binder and sand, fine gravel, or screenings. This surface coating is renewed as often as may be necessary.

Attempts have also been made to produce a more resilient road surface by mixing a mineral oil with the cement. This form of construction is still in an experimental state.

Plate XVI, figure 1, illustrates three types of concrete road, divided as follows: Sections A, B, and C in the first type; sections D and E in the second type; and section F in the third.

Section A represents the subgrade; section B, the oiled concrete, 6 inches thick, mixed in the proportion $1:1\frac{1}{2}:3\frac{1}{2}$ and containing 5 pints of oil to each sack of cement (a traveled surface is here shown); and section C, a 2-inch loam covering, used to reduce evaporation while the concrete is curing. Section D represents the plain concrete, 6 inches thick, mixed in the proportion $1:1:3\frac{1}{2}$ (the illustration shows a floated surface); and section E represents the 2-inch loam covering used to reduce evaporation while the concrete is curing. Section F shows the plain concrete, 6 inches thick, with a bituminous surface consisting of from one-third to one-half gallon of bituminous cement per square yard and sufficient torpedo sand or stone chips to provide a satisfactory wearing surface.

ASPHALT-BLOCK ROADS.

Plate XVI, figure 2, represents an asphalt-block road.

Section A shows the subgrade; section B, the concrete foundation and curb, mixed in the proportion 1:3:7, with a base 6 inches thick; section C, the cement mortar bed, one-half inch thick, composed of 1 part of slow-setting Portland cement and 4 parts of sand; and section D, the asphalt-block surface, covered with sand which has been screened through a one-eighth-inch mesh screen. This sand should be allowed to remain on the surface 30 days. The surface should then be swept clean. Section E represents the finished surface. The asphalt blocks are 5 inches wide, 12 inches long, and 2 inches thick.

BRICK ROADS.

Plate XVII illustrates the construction of a brick road where frost conditions are encountered, and differs from the other models in that the surface width is 14 feet, including the curb. The crown of the completed roadway is three-eighths inch to the foot.

Section A illustrates the prepared subgrade for the foundation course; section B, the concrete curbing placed along the edges of the road; section C, a stone foundation 6 inches deep; section D, a concrete foundation 6 inches deep, which is often used in place of the stone foundation; section E, the sand cushion 2 inches deep, placed on top of the foundation previously described; section F, the surface before grouting; section G, the expansion joints; and section H illustrates the grouted brick surface ready for travel. In addition, a properly constructed mixing box is shown, illustrating the manner in which the grouting is prepared.

ROAD MACHINERY.

Many good roads were built before the invention of modern road-building machinery, but modern machinery has done much to simplify the process and reduce the cost, especially of hand labor. The power-driven road roller has made possible the construction of a macadam road in a few days or weeks, where formerly traffic was required to make its way laboriously over the loose stones for months before the surface became even reasonably consolidated.

The steam road roller was invented by M. Louis Lemoine, of Bordeaux, France. The French Government granted him a patent in 1859. The first English patent was granted to Messrs. Clark and Bathe in 1863. The first steam road roller used in the United States was imported from England in 1868, and its first use was on the United States arsenal grounds in Philadelphia.

The stone crusher has greatly reduced the labor of preparing the broken stone. It was the invention of an American, Eli Whitney

Blake, of New Haven, Conn., in 1858. He was a nephew of Eli Whitney, the inventor of the cotton gin. Mr. Blake's crusher was used first in Central Park, New York City, in crushing rock for concrete. In 1859 the city of Hartford, Conn., purchased one of these crushers for use in the improvement of its streets and roads. This was the first successful application of mechanical power to breaking stone for road-building purposes.

CRUSHER PLANT.

Plate VI, figure 2, represents a portable stone-crusher plant.

Section A illustrates the stone screenings, commonly called "pea" size; section B, the second course of stone, commonly called "nut" size; and section C, the first course, commonly known as "egg" size.

A stone-crusher plant is indispensable in the construction of first-class stone roads and, if such work is to be done well and cheaply, the plant must be complete and conveniently arranged.

Sometimes the crusher can be located so near the quarry that the rock may be sent down grade in tramcars and delivered to the mouth of the crusher by gravity, thus rendering lifting by hand unnecessary. The crusher should be provided with an elevator and with screens for separating the material into proper sizes. The screens should be divided so that through the section near the upper end may pass fragments not exceeding one-half inch in size, while the second section will allow the passage of stones less than 1¼ inches, and the third section will permit stones less than 2½ inches. Any larger stones will be forced through the opening at the end of the screen, from which they will drop into the tailings conveyor, to be crushed finally or eliminated from the work. The jaws of the crusher should be set so as to make as few tailings as possible.

When soft stones are being crushed, a dust jacket having a 1½-inch mesh may be placed over the first section to eliminate dust from the screenings. For receiving the various sizes of crushed rock, bins with slanting metal bottoms and sliding doors should be provided, so that the materials may be loaded into wagons by gravity.

Two types of crusher are commonly used, one the jaw crusher as shown in Plate VI, figure 2, and the other the gyratory crusher. The jaw crusher is generally used for portable plants. In this machine one of the jaws moves backward and forward by means of a toggle joint and an eccentric, and the stone descends as the jaw recedes. As it returns it catches the stone and crushes it. The maximum size of the product is determined by the distance between the jaw plates at the lower edge.

The gyratory crusher consists of a solid conical iron shaft, supporting a heavy mass somewhat like an inverted bell. By means of an eccentric a rotary motion is given the shaft so that every point of its surface is successively brought near the surface of the " bell," and the rock caught between the shaft and " bell " is crushed.

The gyratory crusher will not produce as many flat pieces or tailings as the jaw crusher, because the stones must come in contact with two curved surfaces at the same time before they are broken.

ROAD GRADERS.

Figure 1 shows in miniature a machine which is used in building earth roads and in preparing the subgrade for macadam roads. The frame, which is on wheels, supports an adjustable scraper blade, the front end of which may be used to plow a furrow, while the rear end pushes the earth toward the center or distributes it smoothly. The blade may be set at any angle or tilted either backward or forward.

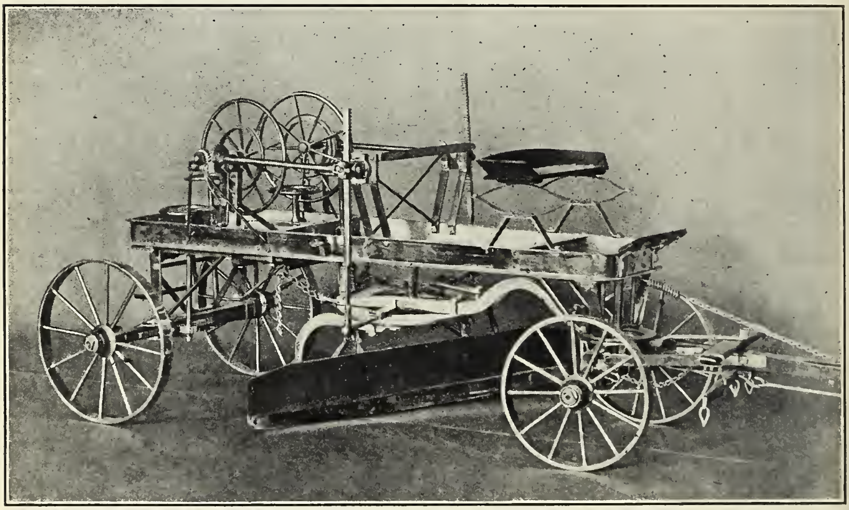

FIG. 1.—Model of road grader.

In building the earth road with the road machine a furrow is first plowed with the point of the blade where the outside of the ditch is to be located. The blade may be made to penetrate hard or stony ground by elevating the rear end considerably and by using only the point of the blade for such plowing.

The team should be driven so that the point of the blade will follow the furrow made on the first trip, plowing a full furrow with the advance end of the blade and with the rear end dropped somewhat lower than before.

The machine should be guided gradually toward the middle of the road, so that it will move the earth previously plowed toward the center. This is done by slightly elevating the rear end of the blade to allow the earth to distribute under it and to give the necessary crown to the sides of the road.

It is advisable to use the machine when the ground is pliable, best of all in the early summer, in order to give the loose earth time to settle and pack before the fall rains. If the work is done in the fall, not more than 3 or 4 inches of loose earth should be put on at one working.

If the side of the road is covered with sod, this should be removed, and the earth from the side ditches should be used to replace it, if necessary.

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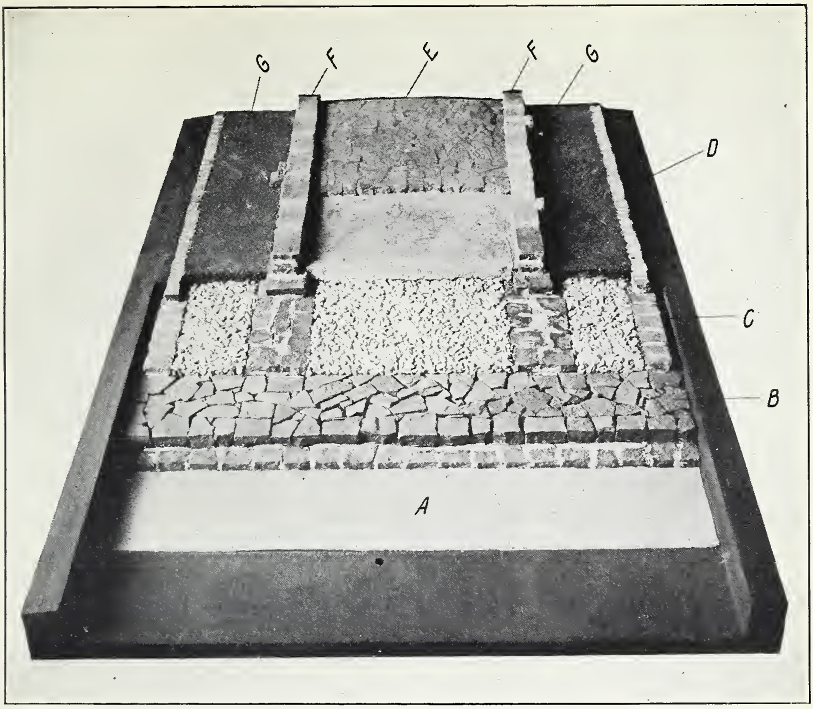


FIG. 1.—MODEL SHOWING THE APPIAN WAY (300 B. C.).

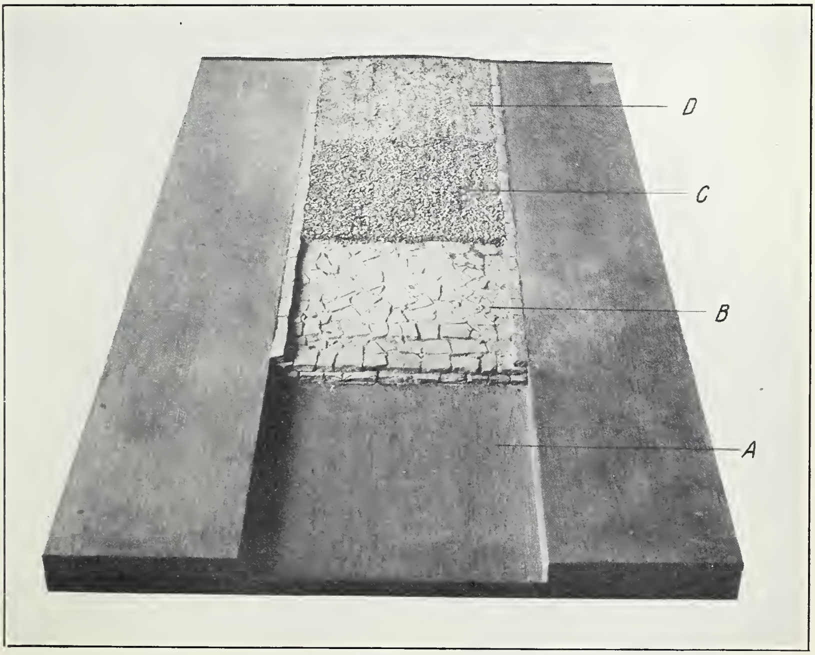


FIG. 2.—MODEL SHOWING A FRENCH ROAD BUILT BEFORE 1775 (ROMAN METHOD).

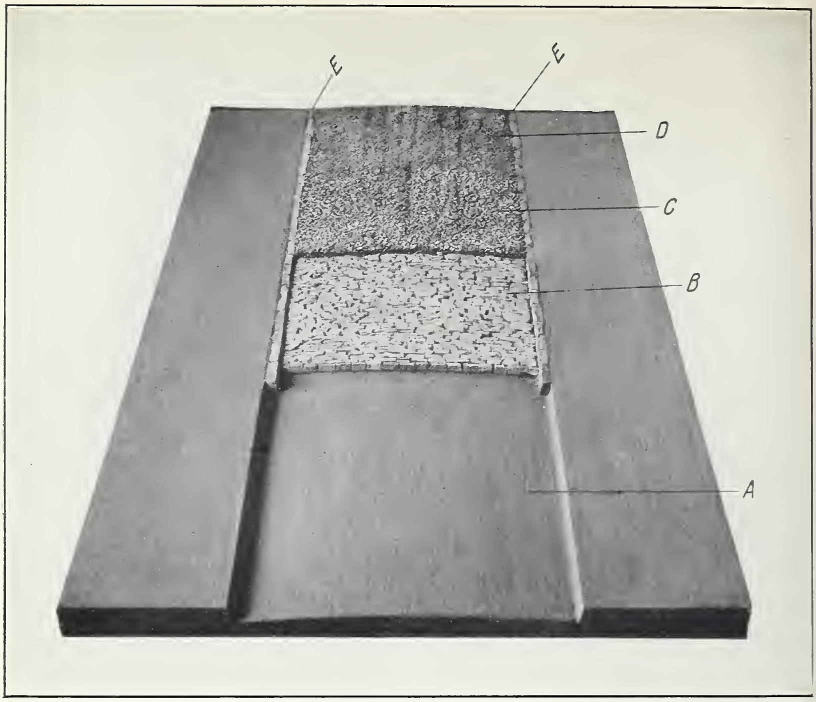


FIG. 1.—MODEL SHOWING A FRENCH ROAD OF TRÉSAGUET, BETWEEN 1775 AND 1830.

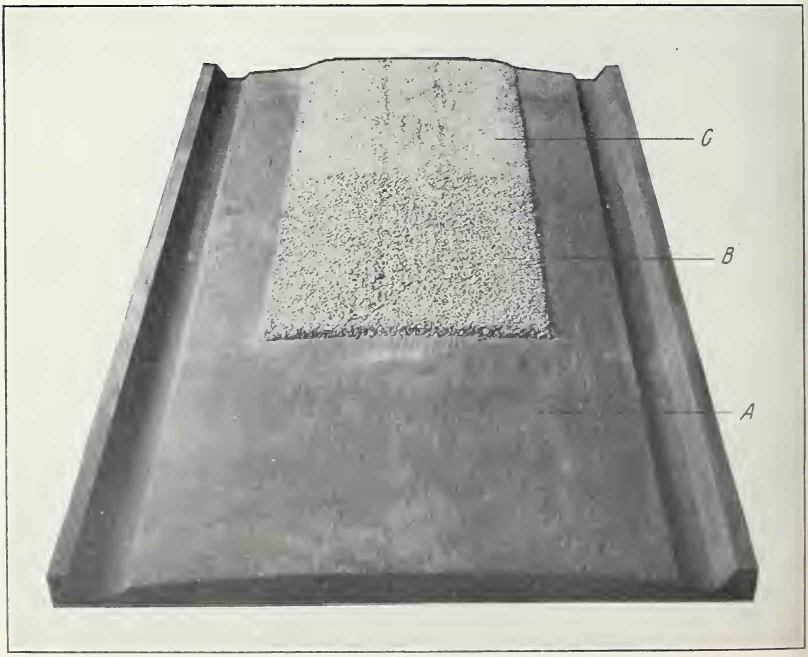
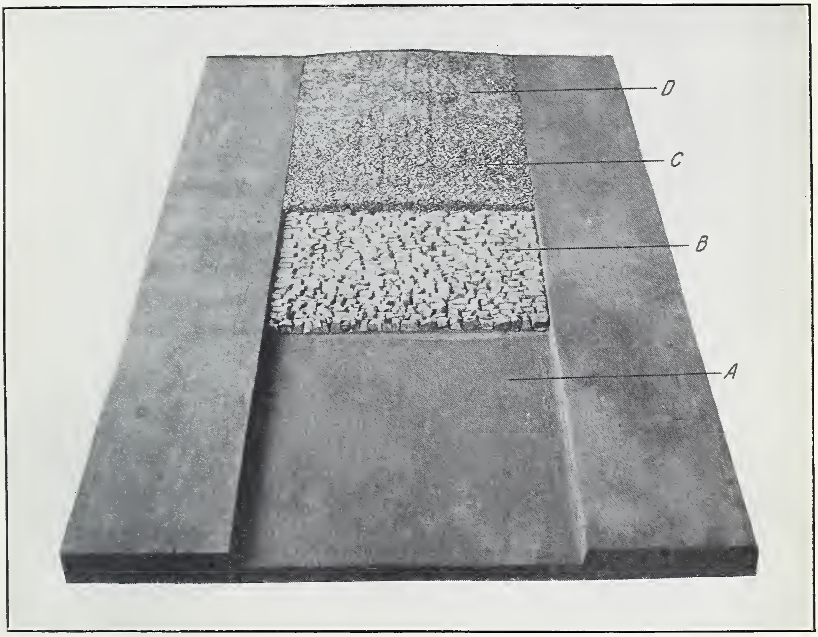
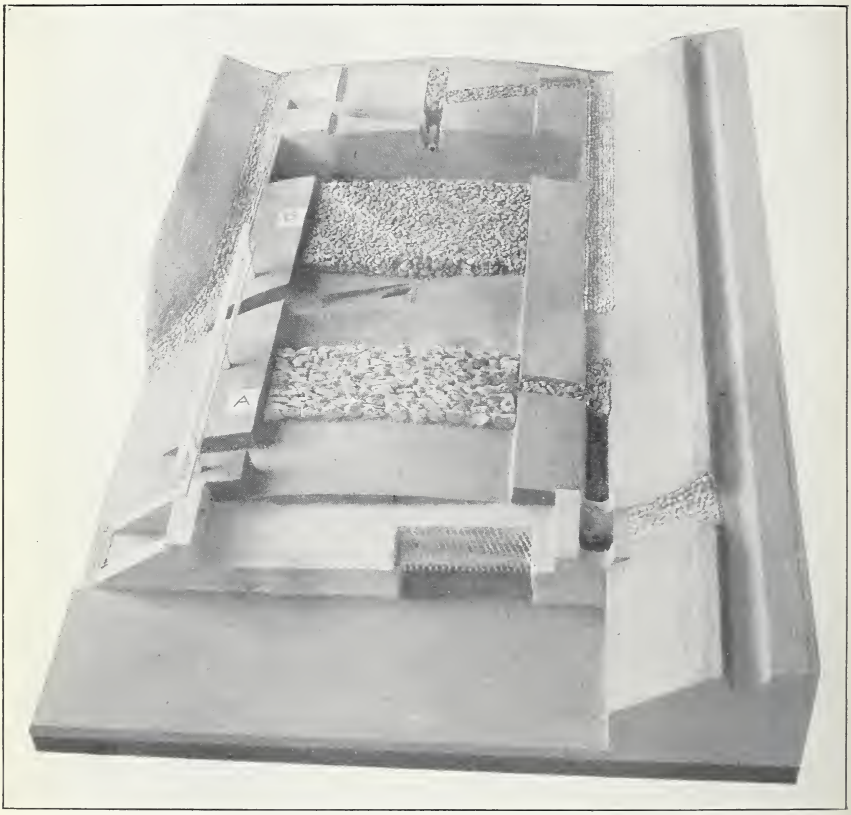


FIG. 2.—MODEL SHOWING A MACADAM ROAD OF THE TYPE BUILT BY MACADAM (1816).



MODEL SHOWING A TELFORD ROAD OF THE TYPE BUILT BY TELFORD (1820).



MODEL SHOWING VARIOUS METHODS OF ROAD DRAINAGE.

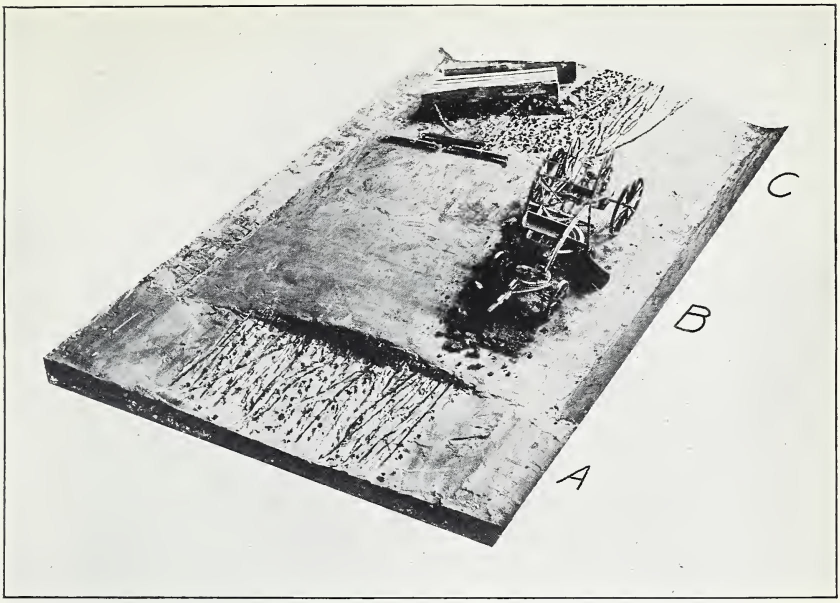


FIG. 1.—MODEL OF AN EARTH ROAD, SHOWING SPLIT-LOG DRAG AND ROAD GRADER IN OPERATION.

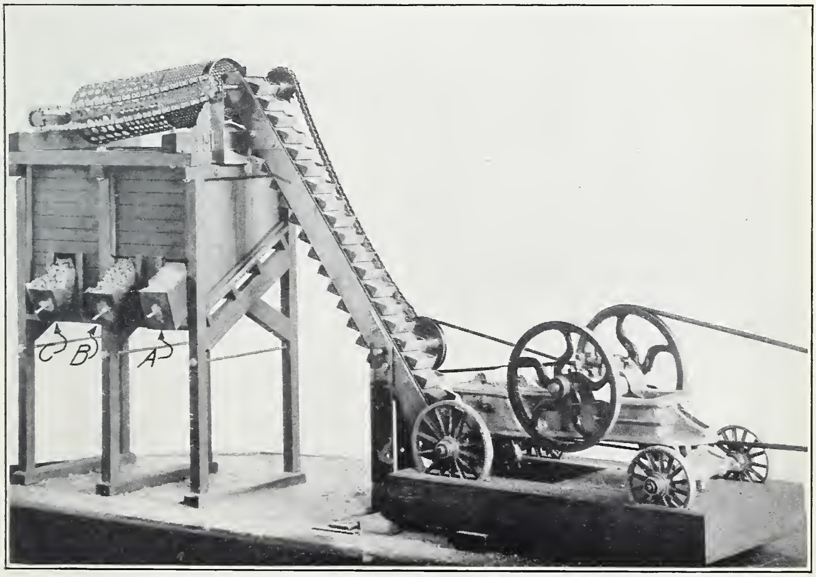
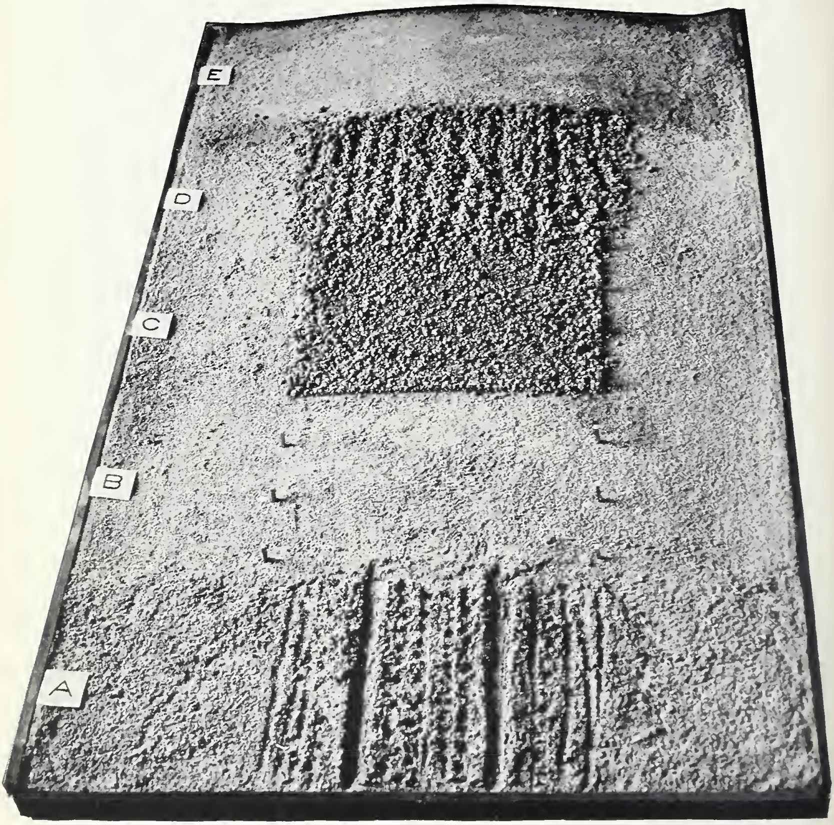
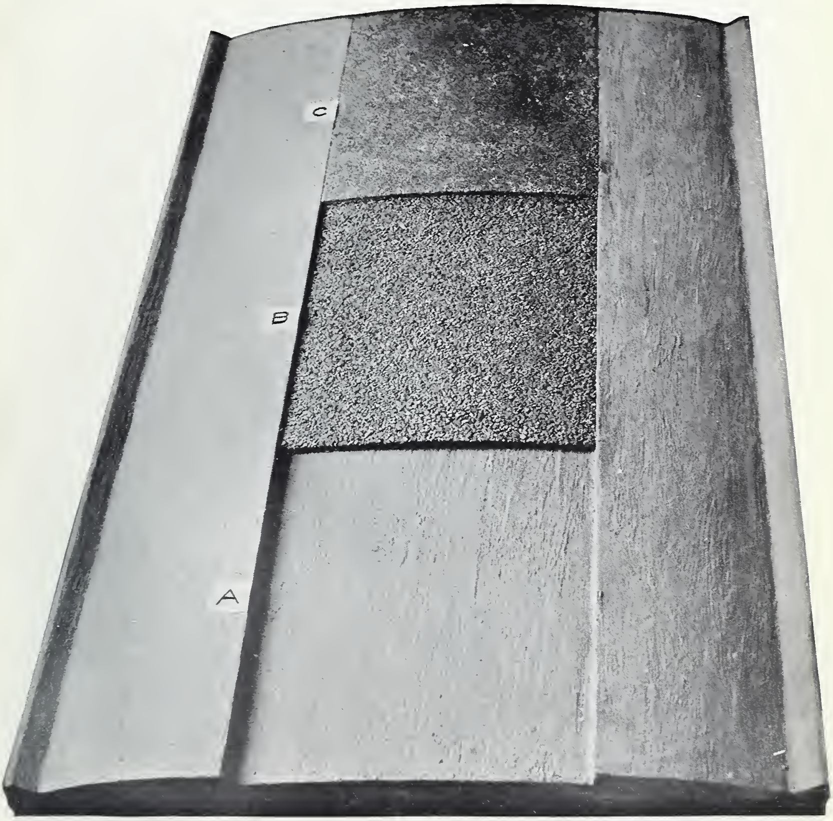


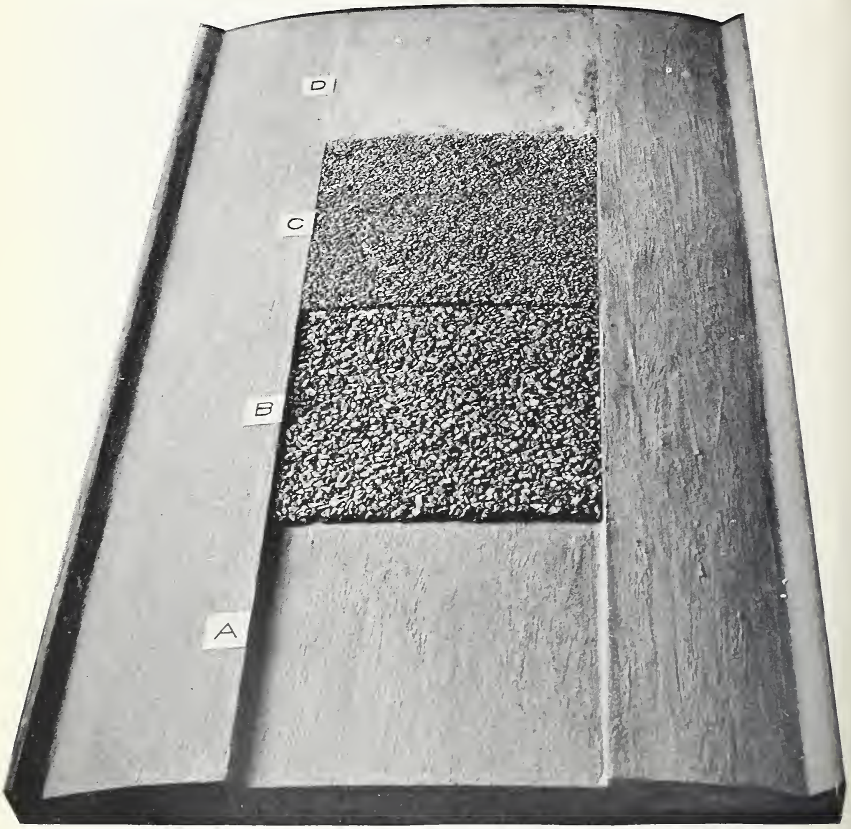
FIG. 2.—MODEL OF PORTABLE CRUSHING PLANT IN OPERATION.



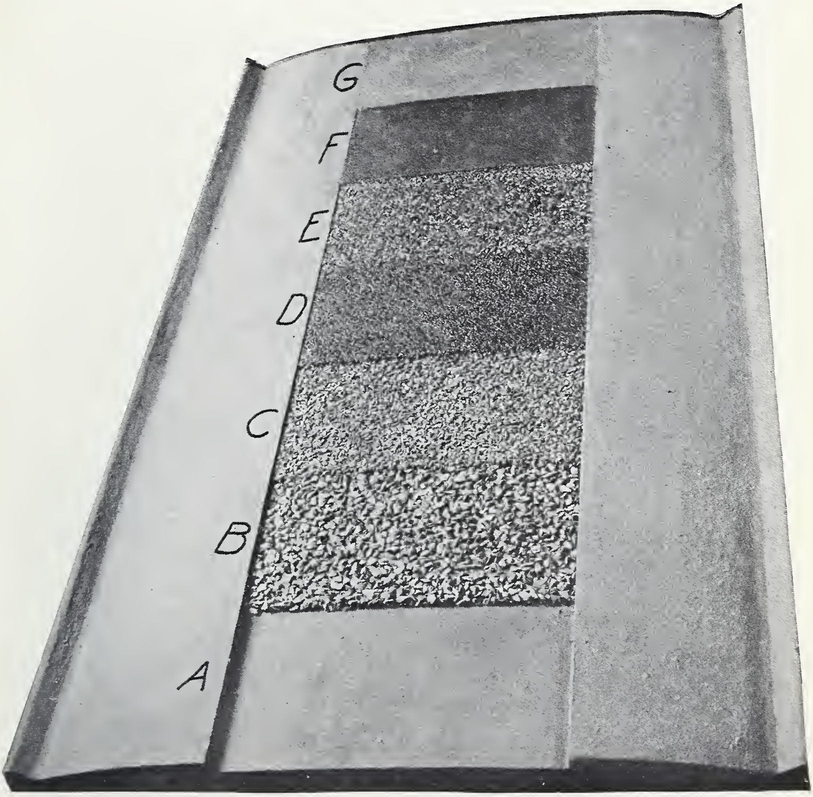
MODEL OF A SAND-CLAY ROAD.



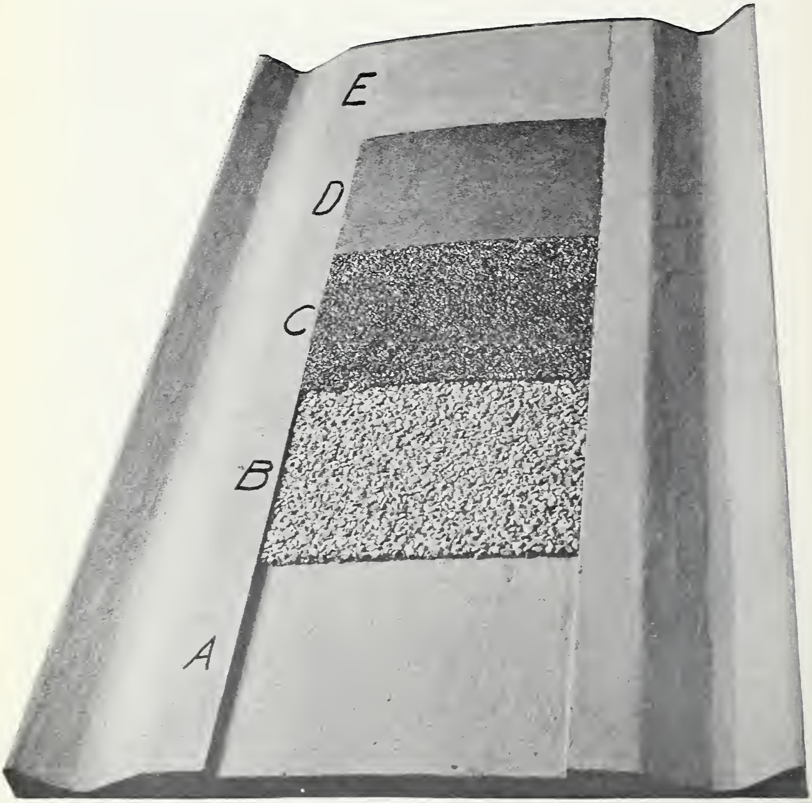
MODEL OF A GRAVEL ROAD.



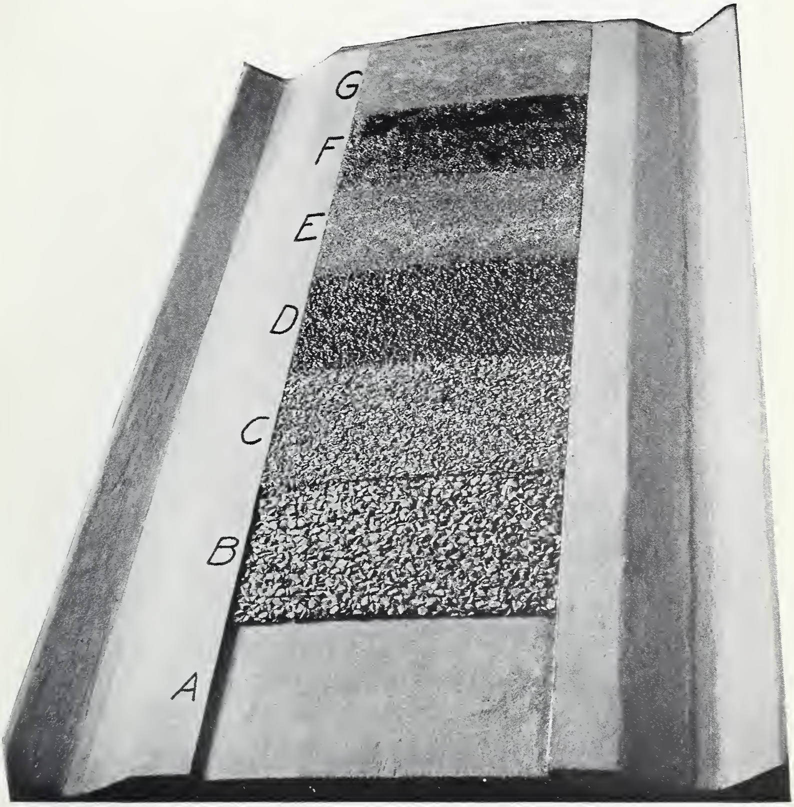
MODEL OF A WATER-BOUND MACADAM ROAD.



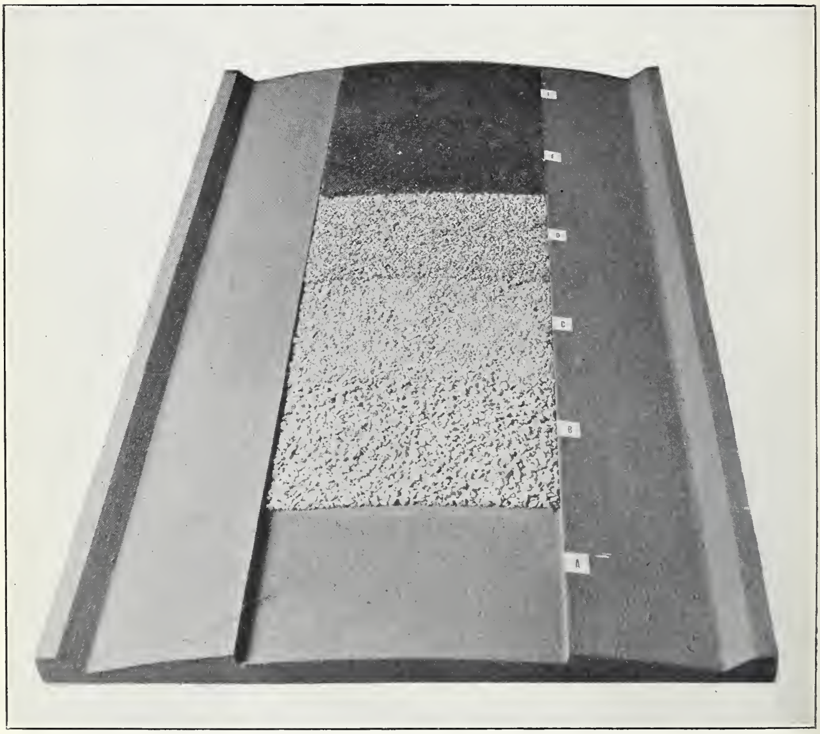
MODEL OF A BITUMINOUS MACADAM ROAD—PENETRATION METHOD.



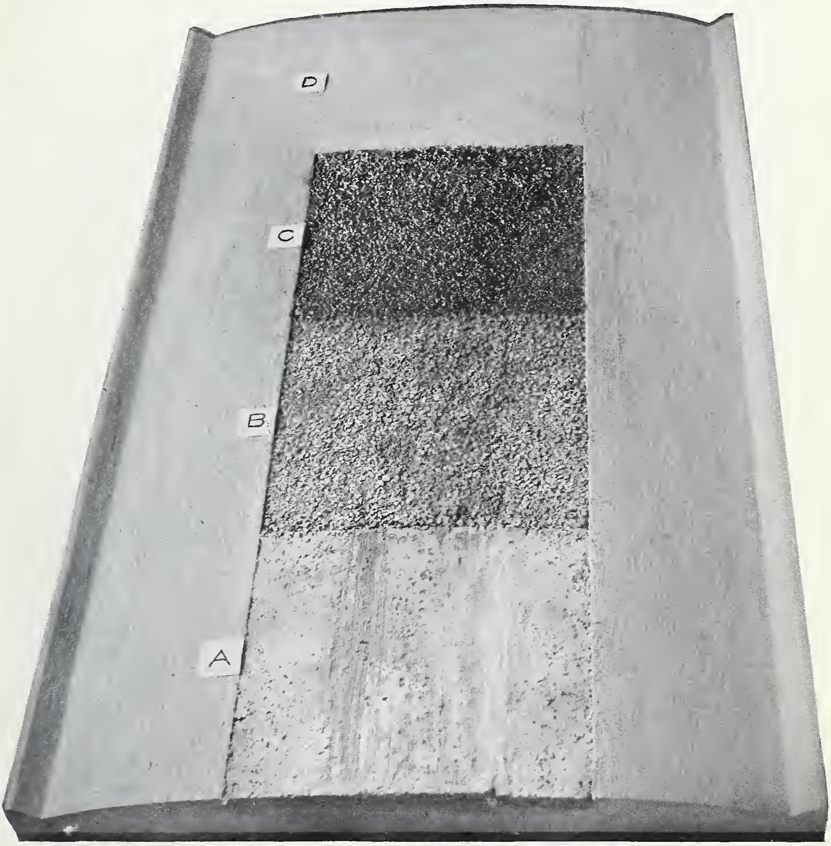
MODEL OF A BITUMINOUS MACADAM ROAD—MIXING METHOD.



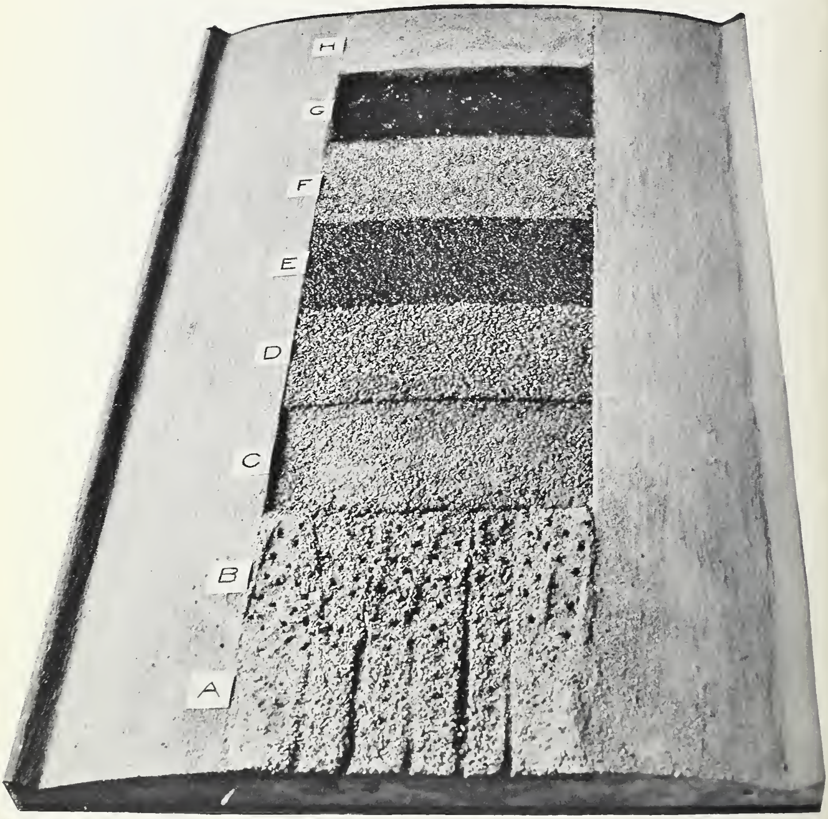
MODEL OF A BITUMINOUS MACADAM ROAD—PREPARED-FILLER METHOD.



MODEL SHOWING A ROCK-ASPHALT MACADAM ROAD.



MODEL SHOWING REPAIR AND MAINTENANCE OF MACADAM ROADS—SURFACE TREATMENT.



MODEL SHOWING REPAIR OF A MACADAM ROAD—RESURFACING ROAD.

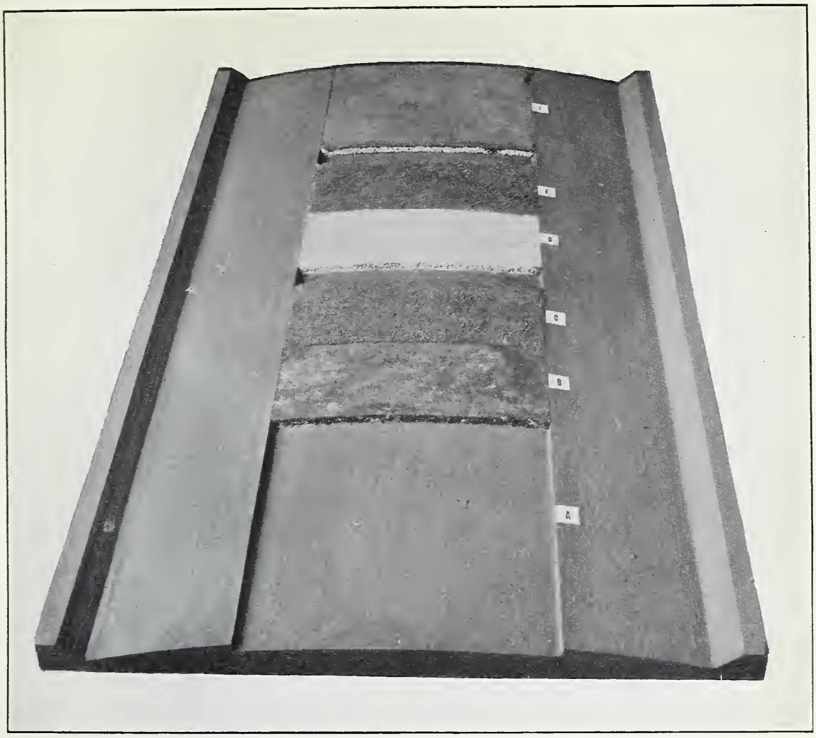


FIG. 1.—MODEL SHOWING THREE TYPES OF CONCRETE ROAD.

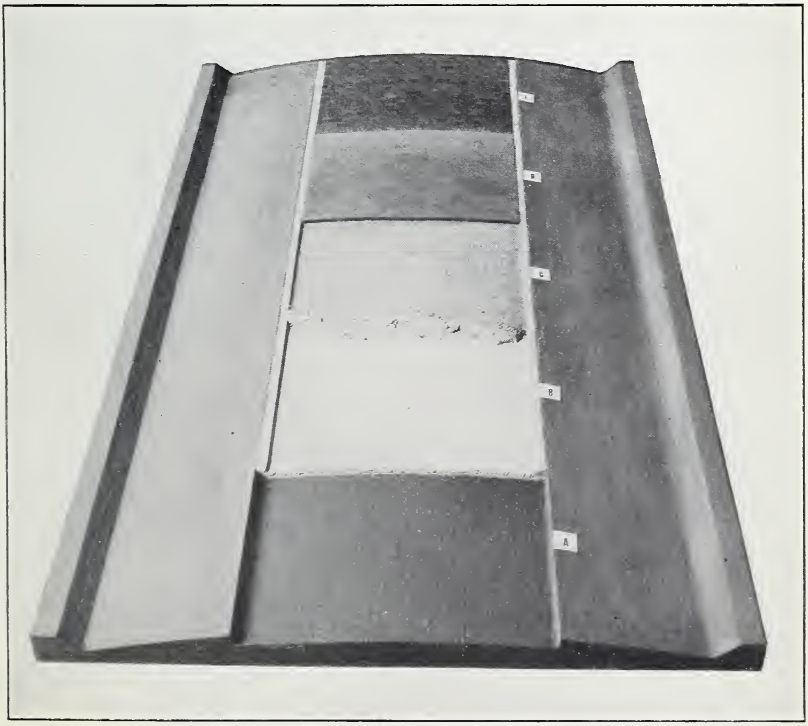
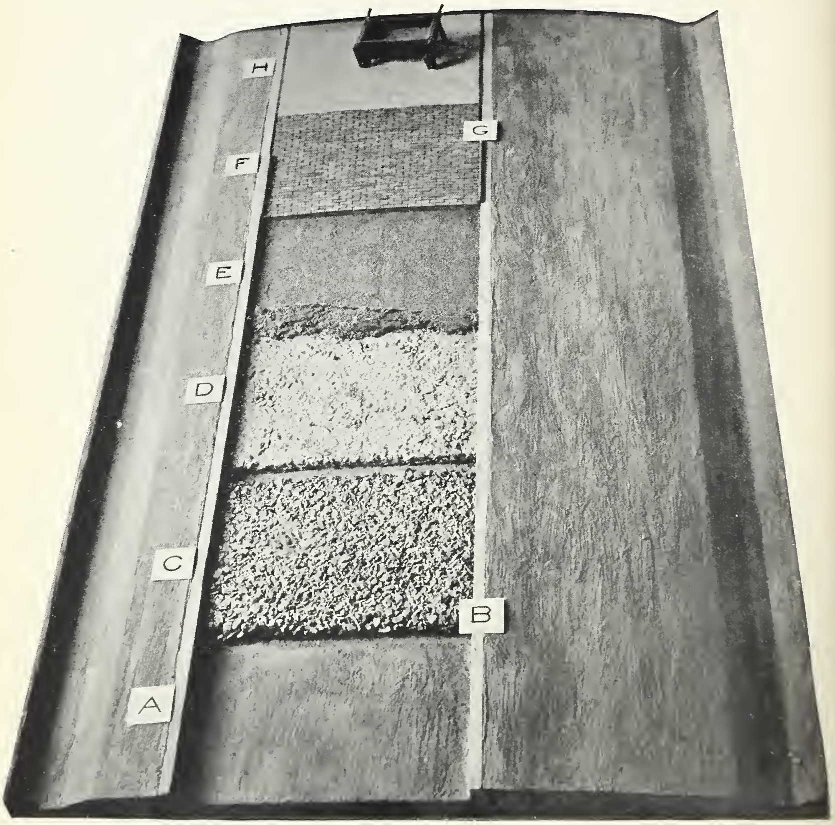


FIG. 2.—MODEL SHOWING AN ASPHALT-BLOCK ROAD.



MODEL OF A BRICK ROAD.